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APPENDIX VI

# ENGINEERING-ECONOMIC ANALYSIS OF SHORE PROTECTION SYSTEMS: A BENEFIT/COST MODEL

Prepared for

U.S. Army Corps of Engineers
North Central Division
Chicago, Illinois

Contract No. DACW23-75-C-0027
Reference Contract Modification P00001

By

Coastal Zone Laboratory
The University of Michigan
Ann Arbor, Michigan

John M. Armstrong, Associate Professor of Civil Engineering
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This is an appendix to the Summary Report of the Pilot Study Program, Great Lakes Shoreland Damage Study. The decision to invest in a shore protection structure is influenced by a number of variables. To enable shoreline property owners to examine the factors in making investments in shoreline protective structures, the study employs benefit/cost analysis. This economic tool evaluations the net benefits property owners derive from shoreline structures. The model ties together these factors in a computer program that determinates the economic worth of the various protective measures available.

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| Appendix I | Great Lakes Shoreline Damage Survey; St. Louis County, Minnesota |
| Appendix II | Great Lakes Shoreline Damage Survey; Brown, Douglas, and Racine Counties, Wisconsin. |
| Appendix III | Great Lakes Shoreline Damage Survey; Muskegon, Manistee, Schoolcraft, Chippewa, Alcona, and Huron Counties, Michigan. |
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## INTRODUCTION

Severe shoreline erosion on the Great Lakes is a recurring natural phenomenon which has caused substantial economic losses to shoreline property owners. In order to minimize the magnitude of these losses, property owners have invested substantial resources of time and money in shoreline protective structures. These structures are designed to retard or halt the natural rate of shoreline recession during high water periods.

Studies have indicated that an overwhelming number of these protective measures have been unsuccessful. Protective measures that are known to be effective will frequently require a substantial investment that property owners cannot or will not make. Therefore, short-term "stop-gap" measures are commonly utilized. Even if monetary resources are available, there is a lack of familiarity with the engineering requirements for an effective shoreline structure by both shoreline property owners and contractors. Consequently, the investments in many shoreline protective structures are largely wasted.

The decision to invest in a shore protection structure is influenced by a number of variables, which are completely interrelated and make an intuitive approach to decision making difficult. To enable shoreline property owners to examine the many and various factors involved in making investments in shoreline protective structures, benefit/cost analysis is employed. This economic tool will evaluate the net benefits property owners derive from shoreline structures. The calculated net benefits are influenced by changes in many factors such as property values; the effectiveness of protective structures; lake level fluctuations; etc., so that the scope of this study is broad. The final model, which is the outcome of this study, will tie together these complex factors in a computer program that will determine the economic worth of the various protective measures available.

To illustrate the value of this model for decision making regarding shoreline protective measures, an example from the final computer program is provided. A property in West Olive, Michigan, has been undergoing severe bluff erosion (13'/year) throughout the current high water period. The house on this property is presently only 75 feet from the edge of the bluff, so there is a potential danger of damage in the future. A shoreline protective structure will prevent further bluff recession to some extent, and thus decrease the danger of damage to this home. The protection of the house from damage, and the prevention of property value decline due to bluff recession are conceived as the benefits accruing to a shoreline protective structure. The manner in which property values decline as the bluff recedes will be explained in the next section of this paper.

The future benefits and costs resulting from protective measures are brought to the present by calculating the opportunity cost of waiting for the net benefits to accrue to the property owners. Thus

at the time the structure is built there are usually no benefits, but the initial costs of building the structure are present. In this example a wooden groin is constructed which has an initial cost of $60 per front foot. This translates into a present vaue of -$60 per front foot in year 0. After the groin has been in existence for one year the net benefit has increased to -$32.97 per front foot because the groin has reduced bluff erosion and the assocated property value decline. By the end of the second year the net benefits are positive ($22.75/front foot) as a result of further protection of bluff loss. After ten years the wooden groin would yield the shoreline property owner a present value of $29.78 per front foot. The present value of the structure after ten years is used for comparison purposes with other structures, because some short-term structures may have a high initial effectiveness, but provide no long-term benefits. In this example situation the present value of a wooden seawall after ten years is $98.41 per front foot, even though the structure fails after six years. A steel seawall yields $47.52 per front foot after ten years. A sandbag groin had a present value of -$49.42 per front foot, and stone revetment -$4.12 per front foot after ten years.

This model accounts for the fact that these protective measures are not 100 percent effective over ten years by reducing the benefits as these structures become less effective. If a protective structure is not 100 percent effective, bluff recession will continue, if only to a minor extent, and therefore there will be some loss in property value. By the same token, we may expect lake levels to decline at some time within the next ten years, and therefore bluff recession will be reduced. The model will account for any decline to the extent that we can predict lake level fluctuations.

The benefit/cost model also measures the net benefits of moving a home back from the bluff, an alternative to building a shoreline protective structure. A prerequisite to home moving is that the lot be deep enough to move the home an adequate distance to ensure that there will be no danger of damage within the near future. The cost of moving the house in this example would be $60 per front foot, but the present value of such a move is $104.54 per front foot. The home moving option had the highest present value of any of the alternatives studied, and therefore the property owner would probably want to move his home. There are several limitations to the model which will be discussed throughout the text, but this example should make apparent the value of the model for rational decision making.

The benefit/cost model is based on the idea of economic efficiency, as perceived by the market. It is important that the concept of market decision making be distinguished from other approaches to economic efficiency. The market is an average of individual values; in this case, market values for shoreline property. The market value may differ from the personal value placed by a particular shoreline owner on his property. For example, a family may have owned a cottage

on the lake for three generations. The value of that property to the present owner is probably much higher than the market value. Such subjective values are very important, and may be the decisive factors in determining how much is invested in shoreline protection.

This study, however, will concentrate on market values for two reasons:

1. It is nearly impossible to account for each individual's values regarding shoreline property.

2. An individual can take the recommendations of this economic analysis and alter them according to his personal preferences.

It is assumed that each shoreline property owner is an entrepreneur seeking to maximize the return on his investment in shoreline property. The fact that most shoreline owners probably do not view their property strictly as an investment does not reduce the validity of this approach. Given the value of an individual's property, the rates of recession, etc., the amount of money that should be invested in a shoreline protective structure will be defined so that the property value saved by protection against erosion justifies the cost of a shoreline protection structure. Consequently, a property owner would be able to sell his property at a price that is now greater by at least the cost of the shoreline protection structure than if erosion had continued unimpeded. This type of analysis will provide shoreline property owners with a framework for making rational decisions concerning protective structures.

The shoreline property owner may deviate from the market solution to the extent that his personal values differ. However, if an owner's value of his property is less than the market's, it is in his best interest to sell that property. Thus the investment dictated by the market (if any) would be the minimum that a property owner would expend. This concept will be articulated more thoroughly in the text.

The following sections discuss in detail the major elements of the decision analysis model. Various hypothetical examples are used to clarify the operation of the model. The reader should keep in mind that the major purpose of this first phase of the study was to produce a model methodology upon which future improvements and refinements could be made.

EROSION INDUCED PROPERTY VALUE LOSS

One of the major elements in constructing a model for shore protection investment is the change in the value of shoreline property during periods of active erosion. Since this study is concerned with the market's evalaution of decreases in property value, real estate appraisers with experience in selling shoreline property were consulted. The data utilized in the formulation of this model was obtained from appraisers in Berrien County, Michigan. In Phase II of the benefit/cost model which is now being proposed, real estate appraisers from several areas in Michigan will be consulted to ensure that the model is more universally applicable.

A benefit/cost questionnaire (see Appendix H-I was mailed to 300 shoreline property owners in Berrien County and Ottawa County, Michigan, in February 1975. The purpose of this questionnaire was to determine how shoreline property owners felt their property value had declined as a result of bluff recession. In addition, questions concerning the aesthetic enjoyment derived from shoreline property were asked. The results were used to compare with realtor estimates of changes in these values. However, the responses of shoreline property owners were not used in the formulation of the model for two essential reasons. First, since no sophisticated sampling techniques were employed, the property owners sampled may not be representative of the entire population. Second, and more important, the responses of individuals tend to be subjective and lack a thorough knowledge of the market for shoreline property. If this model is to be of any value, it must be based on objective criteria, for otherwise decision making would rely on the uncertainty that now exists.

The responses to the questionnaire regarding shoreline property owners' experience with protective structures were taken into consideration, and will be used in proposed Phase II of this study as data on structure effectiveness and cost.

The manner in which property values decline as the bluff recedes was found to be somewhat irregular. Instead of a constant loss of value as the depth of the property decreases, major declines in value occurred as the bluff reached various depths. This was due to the presence of three major components of shoreline property value:

1. The Structure Value which includes the house, if present, and any related structures (sheds, garage, etc.).

2. The Simple Land Value which is the value of the lot after subtracting its value due to lakeside location.

3. The Aesthetic Value which is the additional value of the lot due to its lakeside location.

The Simple Land Value plus the Aesthetic Value equal the total value of the lakeside lot. Each of these values will be discussed in turn.

## The Structure Value

Of the three components, changes in the value of a lakeside home were found to be the most sensitive to erosion. Any loss in structure value can be attributed to a fear of damage to, or loss of the structure, as perceived by the market (prospective buyers). For example, if the distance from the house to the bluff is 200 feet, a prospective buyer could feel fairly certain that the house would be in no danger for many years, given the average rates of erosion in that area. However, if the distance from the house to the bluff was only 100 feet, a prospective buyer may be justifiably concerned that the house would be in danger after another period of high water. Thus there is an element of risk involved, and in terms of market theory, an investor would require a higher rate of return on his investment. In terms of our present example this risk would be compensated by a lower sale price. The presence of an effective shoreline protective structure that the prospective buyer had confidence in would also minimize the element of risk.

To fully understand the nature of the market for shoreline property, two important characteristics should be noted. First, the demand for the limited amount of shoreline property is extremely high in most areas around Michigan. This, of course, accounts for the high prices associated with shoreline property, but it also attenuates the loss of property value due to risk of erosion.

The second characteristic concerns the psychology of the market for shoreline property. If the market for shoreline property had perfect information concerning recession rates, we would expect that the distance from the house to the bluff at which there was risk from erosion (and thus some loss in structure value) would be a function of recession rates. For example, the distance from the house to the bluff at which the house began to lose value would be greater in areas with high recession rates than in areas with lower rates. However, consultation with realtors have indicated that the market is not so discriminating. If one subarea within the total area is experiencing severe erosion, that subarea can influence the way in which prospective buyers perceive the risk factor in the total area.

An example from the Benton Harbor, Michigan area will illustrate this point. There is a reach of coastline approximately two miles long, located south of the Benton Harbor pier, that has experienced extremely high erosion rates during the recent high water period. There have been a number of homes that have fallen in, and this severe damage has been well documented in newspapers throughout the United States. The erosion rate in this area has been estimated as

high as 60 feet in a year by a local real estate appraiser. Even if this recession rate is in fact smaller by a factor of three, it is still much higher than the recession rates in surrounding areas. Home values in this area have fallen significantly as might be expected. A house that was sold for $42,000 in 1964 was resold in 1971 for $22,000 when it was 150-200 feet from the edge of the bluff. Today that house is hanging over the edge of the bluff.

In an area two-to-three miles south of that house there has been little or no erosion in the past five years because of shallow nearshore topography. An apartment complex in that area, 100 feet from the bluff, was recently sold for $500,000. Its sale price during a low water period would have been at least $800,000. Thus there has been a loss in total market value of 37 percent even though there is no threat from erosion. This situation is common throughout the Benton Harbor area because of the severe erosion in one subarea.

Most prospective buyers of shoreline property are not knowledgeable about shoreline erosion, and may feel that all shoreline property in the area is subject to the same risk from erosion that the one subarea is. The rate of bluff recession will be a variable in determining market value to some extent, as the examples will demonstrate, but the psychology of the market has a strong influence over market values.

The distance from the house to the bluff at which the structure will begin to lose value is thus a function of both the recession rate and the psychology of the market. Consultation with realtors in the Benton Harbor area have indicated that this critical distance is commonly about 100 feet, even though the long-term recession rate may be as low as 0.6 feet per year in that area.* A cursory consultation with realtors in Muskegon County indicated the critical distance to be about 60 to 70 feet, even though there are areas with long-term recession rates much greater than 0.6 feet per year there. The reason for this lower critical distance in Muskegon County is that the area with the highest erosion rate is less than in Benton Harbor. Thus the influence of the psychology of the market is not as pervasive in Muskegon County.

The initiation of structure value decline is not evenly distributed between the edge of the bluff and the house as might be expected. At the critical distance where fear of damage to the house becomes a factor, the structure value will decline approximately 30 percent (see Figure 1). As erosion continues to decrease the distance between the house and the bluff, there will be no further decline in property value for the next 20 to 25 feet (using Benton Harbor as an example). At this point, say 75 feet between the house

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*Martin Jannereth, Michigan Department of Natural Resources, personal communication, 1975.

and the bluff, there will be a further gradual decline in structure value as bluff recession continues. While it is true that there will not be a specific decline in the structure value for every additional foot of bluff recession, our model inputs a linear decrease in structure value to simplify those changes. The value changes would not be accurately predictable over such a short range to specifically account for them.

When the distance from the house to the bluff reaches a certain point (approximately 50 feet in the Benton Harbor area), the house can no longer be sold if a mortgage is required. This does not mean that the house has no value; simply that a bank will not assume the risk of lending its money over a long period of time for a house that may fall in the lake. If a prospective buyer has sufficient funds to pay in cash, he may be able to buy that house for 30 percent of its low water value. This 70 percent loss of structure value is based on realtor estimates.

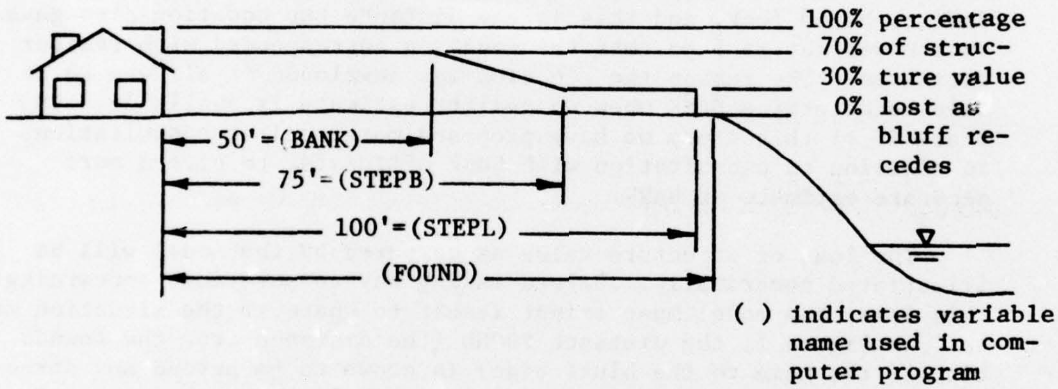



Figure 1. Distribution of structure value over a lakeside lot.

In addition, we have included the high water recession rate as a factor governing the distance at which the house is no longer salable (cannot secure a mortgage). In the subarea undergoing severe bluff recession, this distance may be as great as 150-200 feet. The equation proposed for calculating the distance from the house to the bluff at which the structure is no longer salable is:

$$BANK = [A \times REST] + [1 - A] \times M \times RESR$$

where: BANK = Distance where a mortgage can no longer be obtained.
REST = Realtor estimate of BANK.
RESR = High water recession rate.
A = Uncertainty weighting to realtor estimates.

M = Curve fitting factor; (5) for the
data shown here.

A numerical example should clarify how the computer model calculates this distance. Suppose a realtor estimates that the distance from the house to the bluff at which a particular property would no longer be financed by a bank is 50 feet. For that same property, the high water recession rate has been ten feet per year. "A" is set equal to 0.5. The equation then becomes:

$$BANK = [0.5 \times 50] + [1 - 0.5] \times 5 \times 10$$

which equals 50 feet. If the recession rate were only five feet per year, the distance BANK would be 37.5 feet.

This equation was derived from the few estimates of BANK that were given by realtors. For example, the values in the equation above were taken from a property in Benton Harbor. The realtor estimated BANK to be 50 feet, and this is the distance the equation also gave. Thus M was set at 5 so that the equation corresponded with realtor estimates. The reason the equation was developed at all was to be able to determine BANK when no realtor estimate is available. In Phase II of this study we have proposed more realtor consultation, in addition to consultation with bank officials, to give a more accurate estimate of BANK.

The loss of structure value as computed by the model will be illustrated numerically. Before making any computations concerning this loss, the model must orient itself to whatever the situation may be. In Figure 1, the distance FOUND (the distance from the foundation of the home to the bluff edge) is shown to be beyond any structure value loss. Obviously, this will not always be the case. For example, let us assume that FOUND is initially located in the region of 30 percent structure value loss, between STEPL and STEPB. The estimate of home value input to the program would include the 30 percent loss already suffered. (Home value before erosion progressed to this extent = \$10,000; home value presently = \$7,000.) The model locates FOUND with respect to the critical distances and computes the structure value block as it would have been if the block were as yet undisturbed. The value lost up to the present time is then calculated and stored in variable SVLO--structure value lost old. (SVLO = \$3,000 for this example.) As the bluff continues to recede, a value of SVL (structure value lost) for a given year is computed as follows:

<u>@ time = 0, (initial)</u>

| | | |
|---|---|---|
| STEPL = 100 ft. | BANK = 50 ft. | FOUND = 80 ft. |
| STEPB = 75 ft. | RESR = 15 ft./yr. | SVLO = \$3,000 |

@ time = 1 year later

FOUND - 1 x RESR = 65 ft.

The model calculations are at a point on the slope (Step B) in Figure 1. In all computations, we are concerned with incremental (yearly) losses in value of the home. With the bluff at a position 65 feet from the home, it is necessary to calculate the vertical ordinate of the curve:

SLOPE = 0.4/[STEPB - BANK] = 0.4/25

Y = [STEPB - 65] x SLOPE + 0.3 = 10 x 0.4/25 + 0.3

Y = 0.46

Now the structure value lost during year (1) can be calculated:

SVL = 0.46 x 10,000 - SVLO = $1,600

Updating,

SVLO = SVLO + SVL = $3,000 + $1,600 = $4,600

The available benefit due to the protection of the home in year (1) is $1,600.

@ time = 2 years later

FOUND - 2 x RESR = 50 ft.

We have arrived at BANK, and 70 percent of the structure value is lost. As before, the necessary computations are:

SVL = 0.7 x 10,000 - SVLO = $2,400

Updating,

SVLO = SVLO + SVL = $7,000

In the second year, the available benefit due to protection of the home is $2,400. The model recognizes that $7,000 of the full home value has been lost thus far, while $3,000 remains intact. This same process can continue for up to ten years, or as in this example, until the entire home value is lost.

For other initial positions of FOUND, other procedures, basically the same as those described above are followed.

Simple Land Value

The simple land value is the value of a lakeside lot after subtracting its additional value due to lakeside location. In effect, it is equal to the value of the same size lot in the same area, not bordering on the lake. The additional value of a lot due to its lakeside location is its aesthetic value (to be discussed below). The primary rationale for separating simple land value and aesthetic value is that they are distributed somewhat differently throughout the depth of the lot.

According to realtors in the Benton Harbor area, there is no loss in simple land value of any consequence until the lot recedes to a point where a structure can no longer be built on it. (There are situations, of course, where the lot is greater than 1,000 feet deep, and if eroded to a depth of say 500 feet would probably incur some loss in lot value. Situations such as this are rare, however, and even in this case the value loss would be minor. Thus the point at which the simple land value would begin to decline would be equal to the depth of the house, plus the set-back limit, plus 25 feet (PLV) to allow for a reasonable distance between the house and the edge of the lot or road.

The set-back limit is the minimum number of feet that a property owner may build a new home from the edge of the bluff, as established by the Michigan Department of Natural Resources. Under Public Act 245, this restriction only applies to undeveloped property in designated high risk erosion areas. If a shoreline protective structure is built that is deemed suitable by the DNR, the set-back requirement may be waived. The model also applies the set-back limitation, as an approximation of the minimum depth of property required to build a structure on (plus house depth and 25 feet) to those properties that are already developed.

If the depth of the property is less than the total given above, the simple land value will begin to decline. This decline in land value will not be distributed evenly over the remaining depth of the lot; as the depth continues to decrease, the lot will become less suitable for any activity. The distribution of simple land value is conceived, therefore, as shown in Figure 2b. The area under the linear distribution is the simple land value of the property. If the distance (PLV) and the simple land value are known, the value of "H" can be calculated:

$$\text{SIMPLE LAND VALUE} = \text{AREA} = 1/2 \times \text{PLV} \times \text{H}$$

$$\text{H} = \frac{2 \times (\text{SIMPLE LAND VALUE})}{\text{PLV}} \ \$/\text{ft.}$$

As the variable W (W = DEPTH - RESR x NUMBER OF YEARS) becomes less than PLV, simple land value is lost. The model calculates the area

of the trapezoid that is lost in year "i" and adds this value to the benefits already computed for that year [i.e., structure (home) benefits].

Figure 2a is another form of Figure 2b. It was derived from Figure 2b to match the way in which other value distributions are depicted. Like the structure value distribution before, it shows the percent of simple land value lost as the bluff retreats. The second order curve shown can be constructed by performing the following integration for a number of distances X:

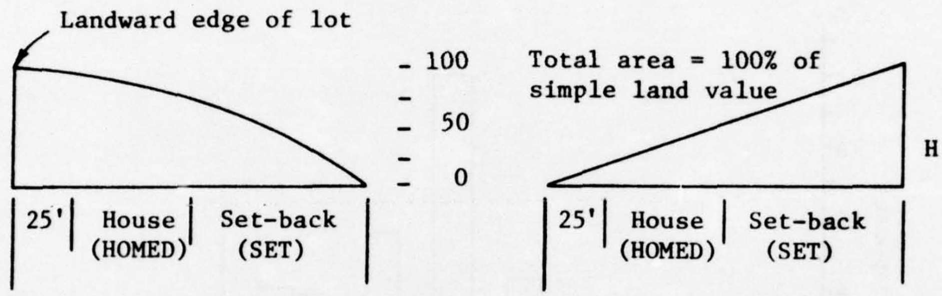



Figure 2a. Percent of inland land lost as bluff recedes

Figure 2b. Distribution of inland land value

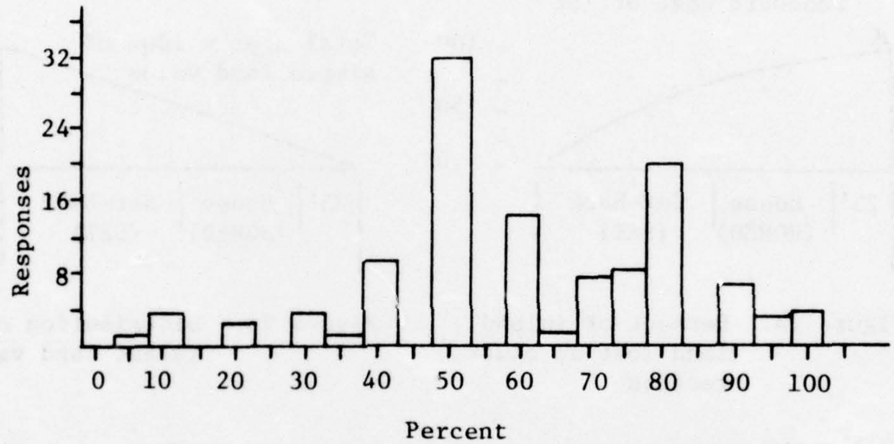
$$\text{TOTAL SIMPLE LAND VALUE LOST through year } i = \frac{1}{\text{TOTAL SIMPLE LAND VALUE}} \int_0^X (H - H's)\, dx$$

## Aesthetic Value

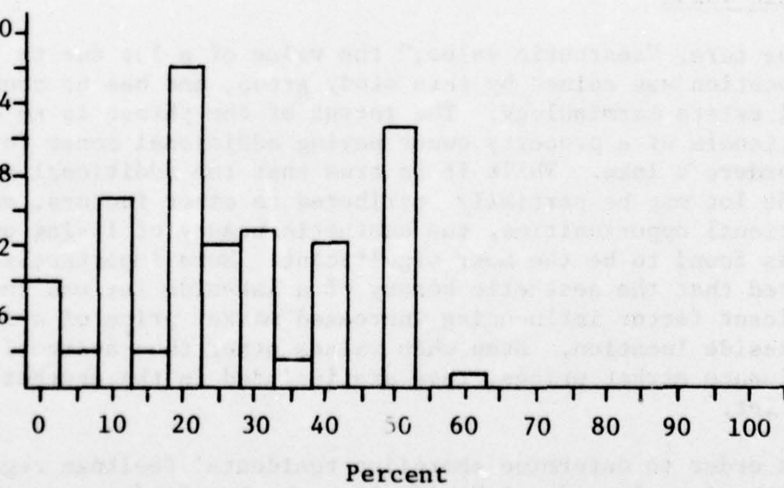
The term, "aesthetic value," the value of a lot due to its lakeside location was coined by this study group, and has no counterpart in real estate terminology. The intent of the phrase is to explain the rationale of a property owner paying additional money for a lot that borders a lake. While it is true that the additional value of a lakeside lot may be partially attributed to other factors, such as recreational opportunities, the aesthetic beauty of living on the lake was found to be the most significant. More importantly, realtors indicated that the aesthetic beauty of a lakeside lot was the only significant factor influencing increased market price of a lot due to its lakeside location. Even when values other than aesthetic beauty do influence market prices, they are included in the aesthetic value of the lot.

In order to determine shoreline residents' feelings regarding the aesthetic value of a lakeside lot, the benefit/cost questionnaire

asked respondents to "indicate the particular values that living on the lake holds for you." They were asked to indicate what percentage of the aesthetic value of the lot could be attributed to the (1) aesthetic beauty, (2) recreational value, and (3) other. For the aesthetic beauty, the mean value given by all respondents was 61 percent of the aesthetic value of the lot. Recreational value was said to account for only 26 percent of the aesthetic value on the average. The distribution of these values, as given by all respondents to the questionnaire is depicted on Graphs 1 and 2. The additional values associated with owning a lakeside lot, such as privacy and a more temperate climate, were included in the category "other," and accounted for 13 percent of the aesthetic value of the lot.




Graph 1. Percentage of Aesthetic Value attributed to the aesthetic beauty of a lakeside lot.




Graph 2. Percentage of Aesthetic Value attributed to the recreational value of a lakeside lot.

Shoreline erosion will cause declines in the aesthetic and recreational values, to the extent that there is some loss in market value. Most shoreline property owners that responded to the questionnaire felt that erosion had resulted in a decline in the aesthetic and/or recreational value of their property. The mean percentages were a 26 percent decline in aesthetic value and a 35 percent decline in recreational value. To arrive at an estimate of dollar loss for these subjective values, the percent aesthetic value was multiplied by the percentage decline in aesthetic value. This value was then added to the decline in recreational value (computed in the same way) and then added to the computations for the decline in the other values listed. This total was then multiplied by the market value of the property before recession occurred to give a figure for the dollar loss attributed to the aesthetic value of the shoreline property.

The mean for the aesthetic value loss for all areas surveyed was $4,348, with a standard deviation of $5,714. This figure tends to possess an upward bias, because the response to the "other" category in the question, concerned with the percentage decline in these subjective values, also included such factors as fear of erosion, etc.

Consultation with realtors provided a contrasting perspective of how the market perceives the loss of aesthetic value. Initially, there will be some loss in aesthetic value when vegetative cover on the bluff has been removed by erosion. The view from the house is measurably degraded, and the damage caused by erosion and any shoreline protective structure is seen more readily.

It is interesting that the realtors consulted suggested no market value for the recreational potential of the property, even though many shoreline property owners indicated that such value was of some importance to them. When directly asked how much more a property with an adequate beach and access would be worth, as contrasted with property that possessed no recreational value due to the lack of any beach, the realtors replied, "very little, if any." They felt that recreational opportunities might "help the property to sell," but they could assign no tangible market value. It is important to remember however, that any one prospective buyer may pay more for property with a beach than for one that does not. The contention of no market value is again only an average of what all prospective buyers will pay.

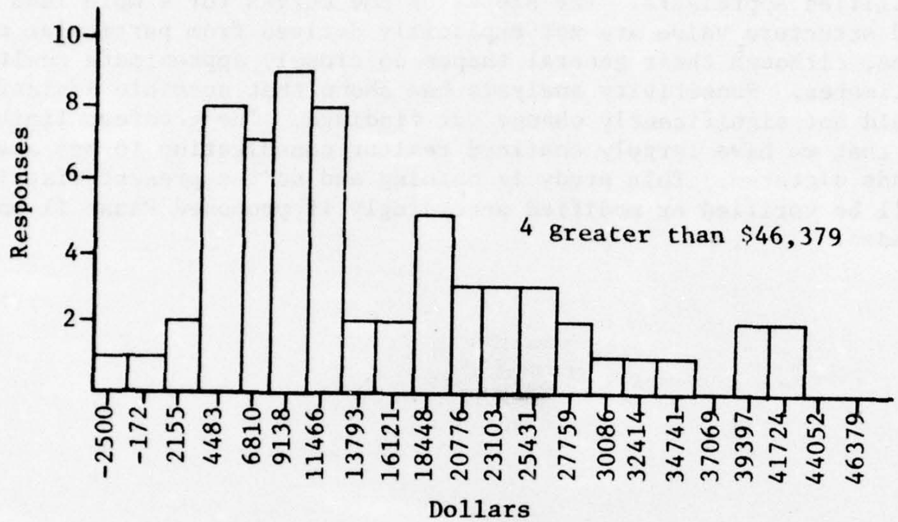
A correlation was run to see if shoreline property owners felt that there was any relation between the number of feet of beach lost during the recent high water period, and the percentage decline in recreational value that they indicated. The results indicated no such correlation; the correlation coefficient being 0.1301. The results of this test are somewhat tenuous, for it is actually the depth of

beach remaining, and the access to that beach that are the important criteria.

The loss in market value that is attributed to erosion of the vegetative cover of the bluff was found from realtor estimates to be 25 percent of the additional value of the lot due to its lakeside location. This 25 percent would also include the "very little" market value decline due to the loss of recreational opportunities.

The 75 percent of the aesthetic value remaining is not lost until the depth of the lot is no longer great enough to build on. At that time the remaining aesthetic value is lost immediately. The logic behind such a distribution may not be readily apparent. Consider a lot that is actively receding. When recession occurs, there is the initial loss of beauty as the vegetation is removed from the bluff. But as recession continues, there will be very little change from the perspective of the market. A highly valued tree may be lost in the process that measurably reduces the aesthetic value to the present owner. However, if that owner was to sell that lot, the prospective buyer would not have been aware of its existence. He is only buying a lot on the lake. In any case, this model is not so precise as to predict such small changes in value. Even if the house on the lot were to fall in and there was enough room to build another structure, the buyer would pay the premium price for the lakeside lot, which includes its additional value due to lakeside location. If the lot receded to a point at which a structure could no longer be built, the remaining 75 percent of the aesthetic value would be lost. There will be an exception to this when a house exists on a lot already too shallow to build another structure. For example, if a house now is located on a lot 125 feet deep, the aesthetic value of the lot will not be lost until the edge of the bluff is near the foundation. Even though the lot may be only 125 feet deep, the homeowner still retains the remaining 75 percent of the aesthetic value of the lot.

The magnitude of the aesthetic value as given by respondents to the questionnaire for all areas was $16,340 (mean value) with a standard deviation of $13,776. According to the respondents, property in the Holland area had the greatest aesthetic value at $28,125, followed by Stevensville-New Buffalo at $20,900, Grand Haven-West Olive at $19,417, and Benton Harbor-St. Joseph at $7,921. The sample size for this question was small, so these values are expressed with caution. Graph 3 shows the distribution of these values for all areas. The negative values are somewhat anomalous, but apparently some respondents felt that bluff recession had been severe enough to cause their lots to be worth less than a lot not on the lake.




Graph 3. The magnitude (in dollars) of the aesthetic value of the lot from all areas studied.

The distributions for structure value, simple land value, and aesthetic value are shown in Figure 3. This combination indicates the total distribution of value across a lot bordering the shoreline in the Benton Harbor area.

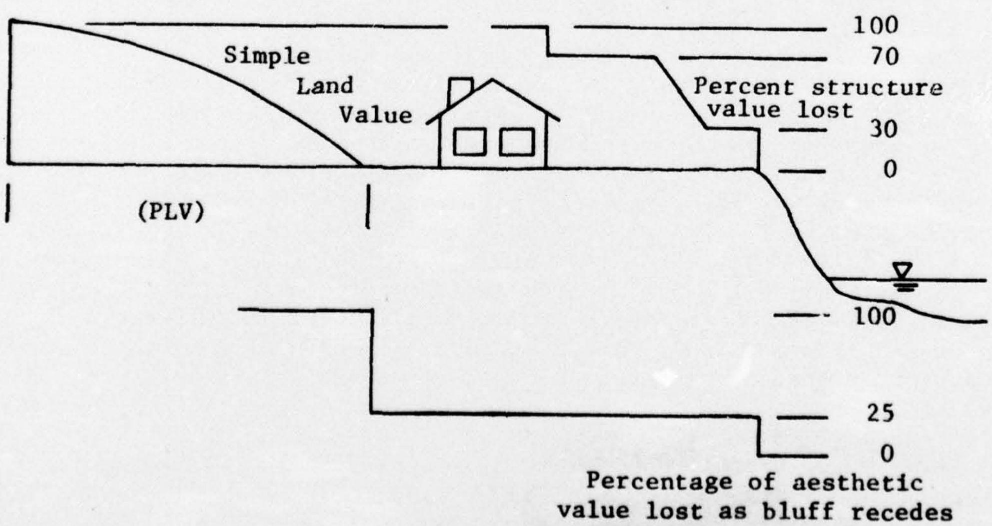



Figure 3. Distribution of total property value over a lakeside lot.

There are limitations to the distribution of value shown above. Wherever possible, these values are the result of consultation with qualified appraisers. The slopes of the curves for simple land value and structure value are not explicitly derived from particular examples, although their general shapes do closely approximate realtors' estimates. Sensitivity analysis has shown that possible deviations would not significantly change our findings. The greatest limitation is that we have largely confined realtor consultation to one area as funds dictated. This study is ongoing and so the present distribution will be verified or modified accordingly if proposed Phase II work is funded.

## BENEFITS OF SHORELINE PROTECTIVE STRUCTURES

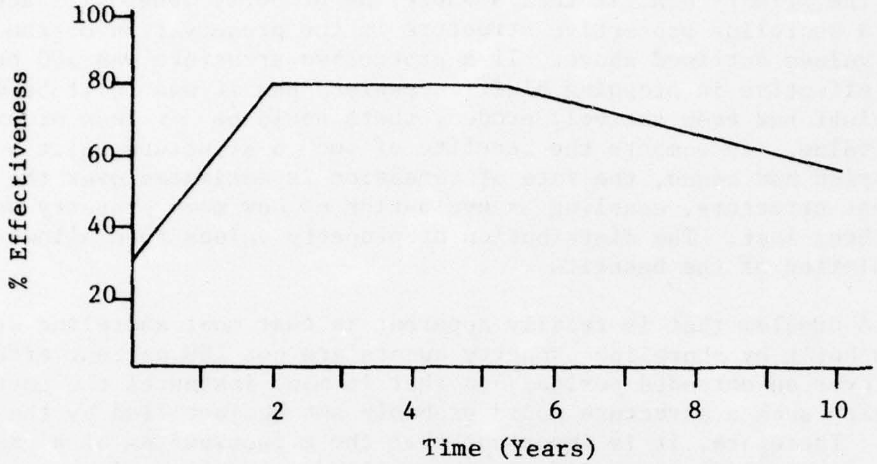
The primary benefit that a shoreline property owner will acquire from a shoreline protective structure is the preservation of the property values outlined above. If a protective structure was 100 percent effective in stopping bluff recession, and it was built before the bluff had been actively eroded, there would be no loss of property value. To compute the benefits of such a structure built before recession had begun, the rate of recession is estimated over the life of that structure, enabling an evaluation of how much property would have been lost. The distribution of property values then allows a calculation of the benefits.

A problem that is readily apparent is that most shoreline structures built by shoreline property owners are not 100 percent effective over an extended period, and that in many instances the cost of building such a structure would probably not be justified by the benefits. Therefore, it is important that the effectiveness of a protective structure over its life is known with some degree of accuracy. In addition, recession rates are affected by lake level fluctuations which are difficult to predict over a long period of time.

This study will bypass some of these uncertainties by drawing from the experience of the authors and others who have worked with shoreline protective structures to derive life-effectiveness curves for various erosion control structures. These curves (see Figures 4 through 9) illustrate how the effectiveness of a structure changes over its life. For example, Figure 7 shows a wooden seawall at 80 percent effectiveness over the first year of its life, and 75 percent for the next year. After two years, the effectiveness of a wooden seawall will begin to decline rapidly such that it is only 20 percent effective after four years. The rock revetment built for $200 per front foot in Figure 9 can be expected to be 100 percent effective in stopping erosion for the first five years, and gradually decline thereafter.

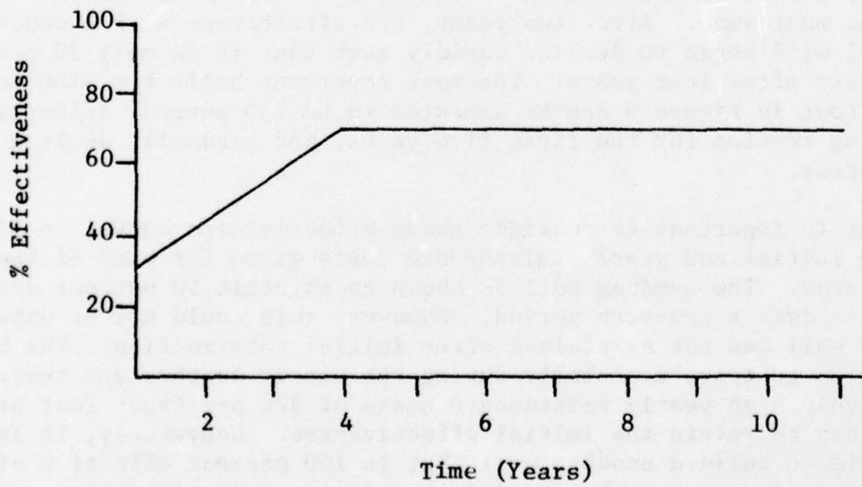
It is important to consider these effectiveness curves in light of the initial and yearly maintenance costs given for each of the structures. The sandbag wall is shown to maintain 50 percent effectiveness over a ten-year period. However, this could not be expected if the wall was not maintained after initial construction. The bags are known to tear, especially during the winter months, and therefore relatively high yearly maintenance costs of $20 per front foot are necessary to retain the initial effectiveness. Conversely, it is possible to build a sandbag wall that is 100 percent effective simply by greatly increasing the initial expenditure and maintenance costs. The figures given for these costs were obtained from contractors who have built these structures on the Lake Michigan shoreline.

Given these curves, one can calculate the rate of bluff recession after the structure has been built and for its life. If the



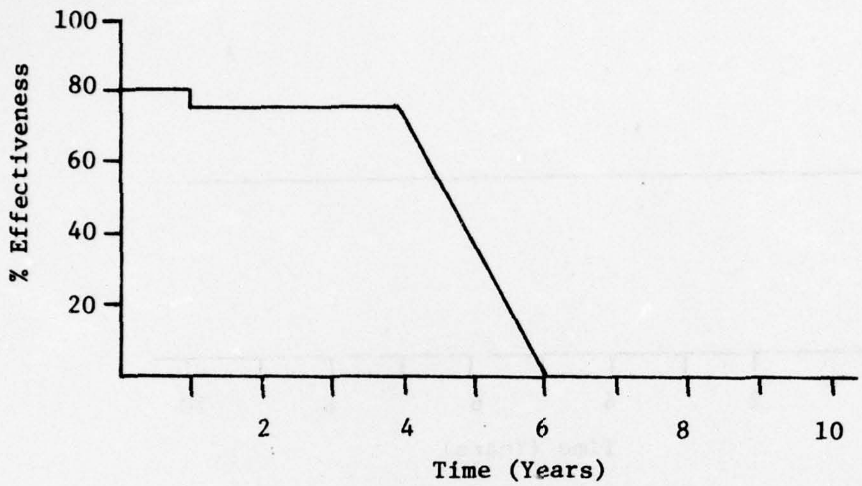

Initial Cost - $60 per front foot of protection
Yearly Maintenance - $6 per front foot of protection

Figure 4. Wood Groin Effectiveness.



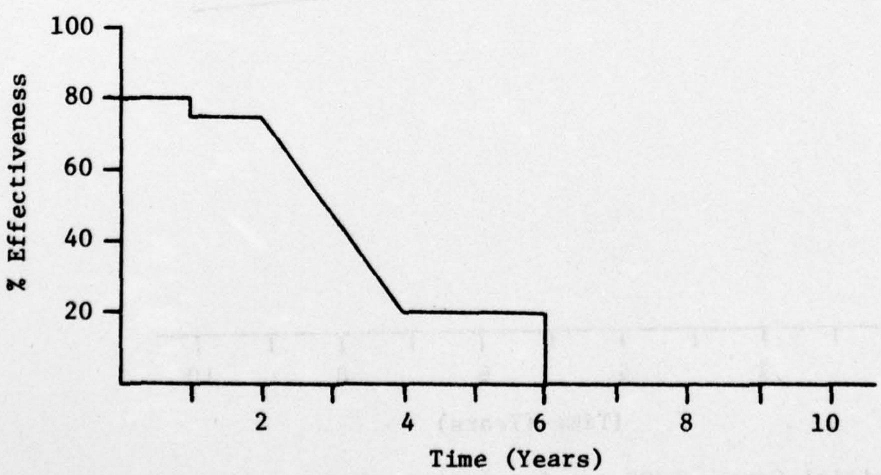

Initial Cost - $50 per front foot of protection
Yearly Maintenance - $20 per front foot of protection

Figure 5. Sandbag Groin Effectiveness.



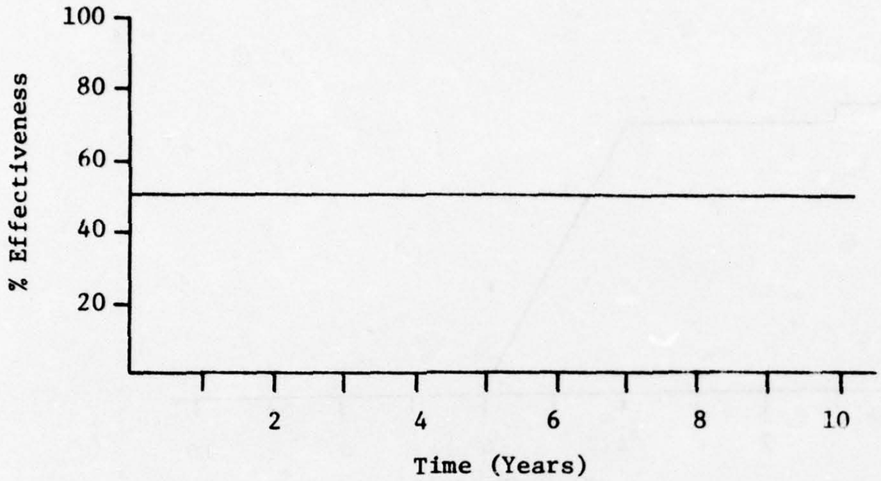

Initial Cost - $85 per front foot of protection
Yearly Maintenance - $0 per front foot of protection

Figure 6. Steel Wall Effectiveness.



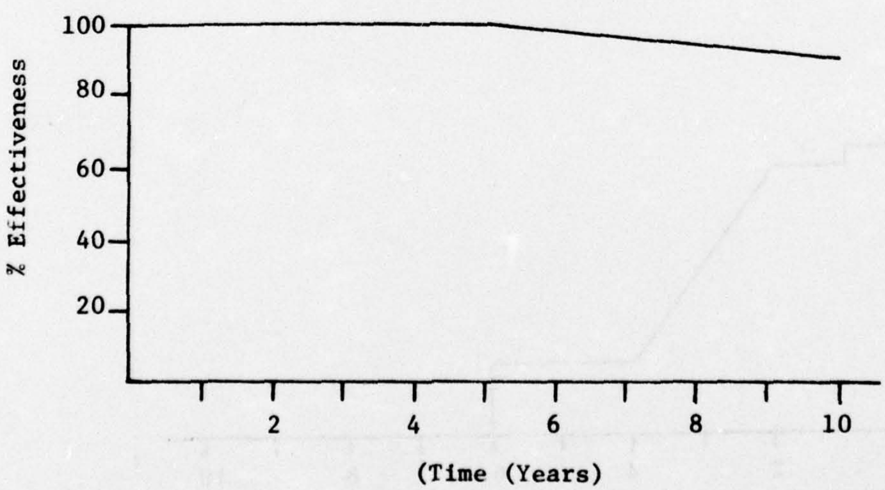

**Initial Cost - $27 per front foot of protection**
**Yearly Maintenance - $2 per front foot of protection**

**Figure 7. Wood Wall Effectiveness**




Initial Cost - \$50 per front foot of protection
Yearly Maintenance - \$20 per front foot of protection

Figure 8. Sandbag Wall Effectiveness.




Initial Cost - \$200 per front foot of protection
Yearly Maintenance - \$0 per front foot of protection

Figure 9. Rock Revetment Effectiveness.

structure is 50 percent effective over its life, the recession rate is expected to be halved for that ten-year period. Given a recession rate of ten feet per year prior to the construction of the structure, the rate would be reduced to five feet per year with the structure present. However, it is being assumed that lake levels remain high enough to maintain this recession rate and that the performance of the structure can be predicted.

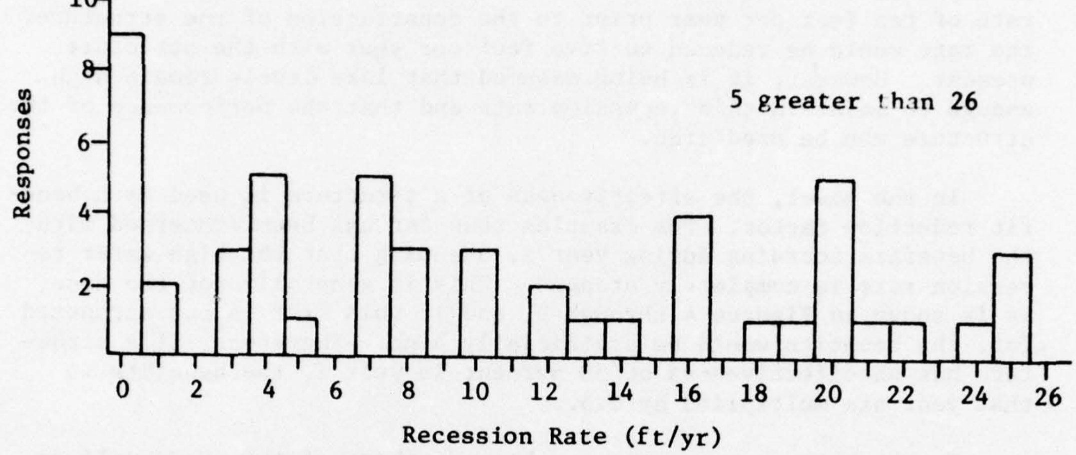
In the model, the effectiveness of a structure is used as a benefit reduction factor. The examples thus far has been concerned with the benefits accruing during year i, assuming that the high water recession rate is completely stopped. This is generally not the case as is shown in Figures 4 through 9, and if this fact is not accounted for, the benefits would be artificially high. Therefore, if a structure has an effectiveness of 50 percent in year i, the benefits in that year are multiplied by 0.5.

To check these assumptions, the next phase of the study will examine the relationships between lake levels, storm intensity, nearshore topography, and structure effectiveness. Using reliable data on wind, fetch, and duration, the probability of a given wave height and period offshore can be calculated. Knowledge of the nearshore topography will enable a computer program to bring the offshore wave into the beach, calculating the way in which the wave is refracted, and the change in height and celerity. Empirical tests can then be employed to study the effect of this wave energy on various structures. In addition, data collection on structure performance by monitoring and surveying will provide further verification of structure effectiveness curves. Some of the data will be taken from Michigan's Demonstration Erosion Control Program, which is monitoring the performance of several "low cost" shoreline protection structures.

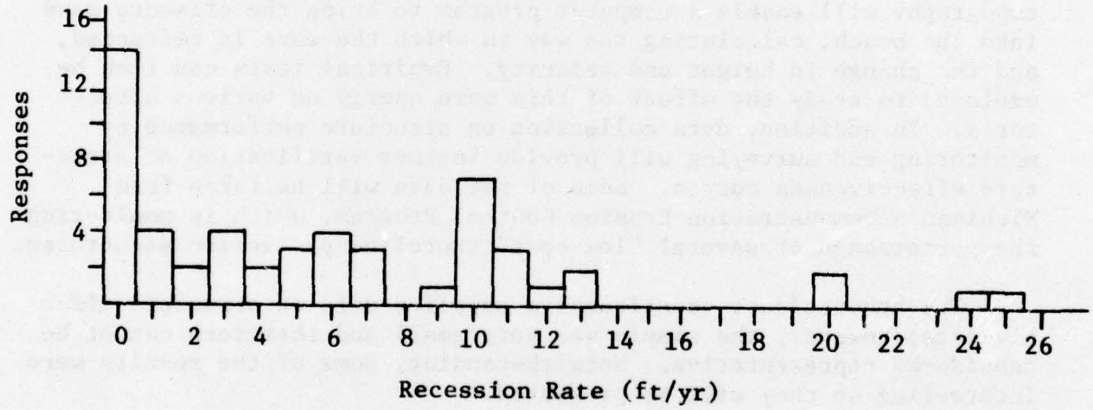
The benefit/cost questionnaire supplied data on structure effectiveness; however, the sample was very small and therefore cannot be considered representative. Notwithstanding, some of the results were interesting so they will be presented.

Several questions were asked concerning the potential danger from bluff recession that shoreline property owners faced to discover whether they thought the problem serious enough to warrant protective action. The mean high water recession rate for all areas surveyed, according to respondents, was 12.36 feet per year. The high water recession rate was calculated by dividing the bluff recession that had occurred during this high water period for each respondent by the number of years they indicated bluff recession had been active. The recession rate for those who had taken protective action was then compared with the recession rate for those who had not. The results are shown in Graphs 4 and 5. It is apparent that the recession rate is lower for those who took no action than for those who did. This would be expected since those owners experiencing the

higher recession rates would be more likely to utilize a protective structure.

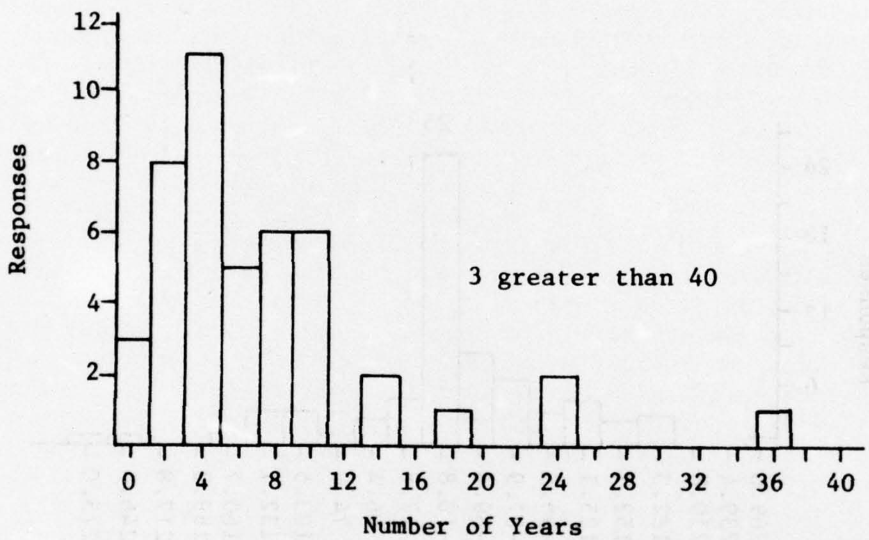



Graph 4. The recession rates for those property owners who took protective action.

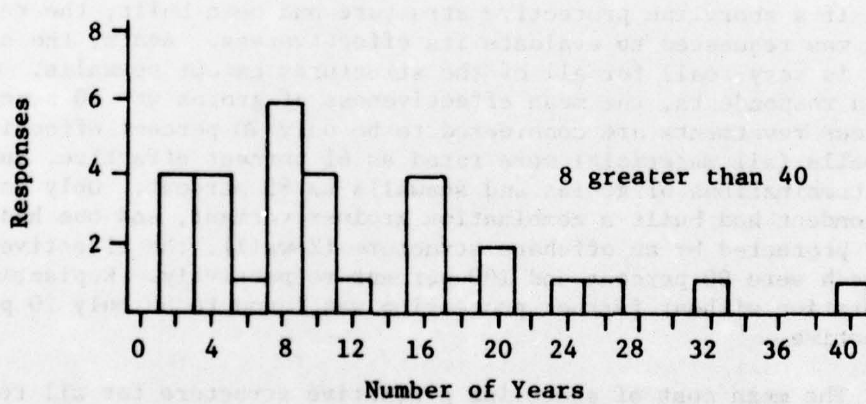



Graph 5. The recession rates for those property owners who did not take protective action.

The time interval before the edge of the bluff would reach the foundation of the house was also categorized according to those who had taken protective action, and those who had not. As shown on Graphs 6 and 7, the majority of the shoreline property owners who had taken action are those who had ten or less years remaining before their houses would be at the edge of the bluff.

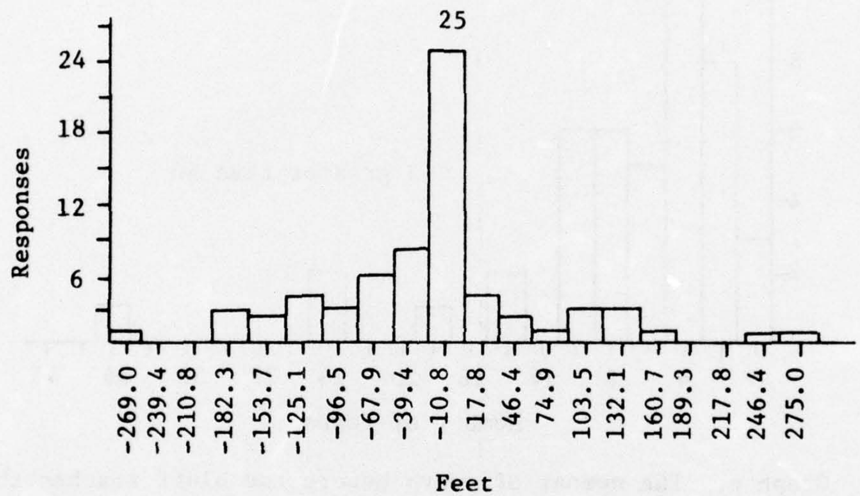



Graph 6. The number of years before the bluff reaches the foundation for those who took protective action.




Graph 7. The number of years before the bluff reaches the foundation for those who took no protective action.

Most shoreline property owners sampled also felt that they had already lost some value from their property as a result of bluff recession. All of the negative numbers (distances) on Graph 8 are an indication of this. The shoreline property owner was asked what the distance from his house to the bluff would be when his property began to lose value. This distance was then subtracted from the present distance of his house from the bluff. These values are again the opinion of the shoreline property owner, but this opinion is important because it is probably the motivating factor behind the decision to build a shoreline protective structure.

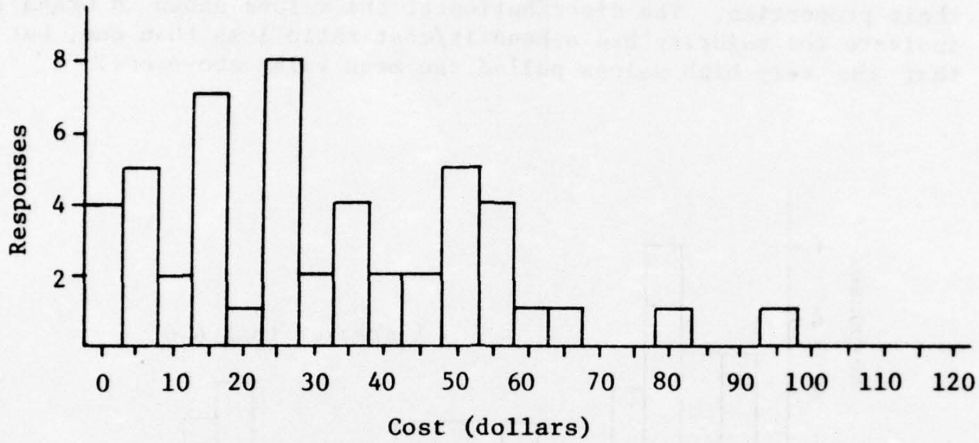



Graph 8. The number of feet after which or before which the property began to lose value.

If a shoreline protective structure had been built, the respondent was requested to evaluate its effectiveness. Again, the sample size is very small for all of the structures except seawalls. Of seven respondents, the mean effectiveness of groins was 60 percent, whereas revetments are considered to be only 40 percent effective. Seawalls (all materials) were rated as 61 percent effective, and the combinations of groins and seawalls as 85 percent. Only one respondent had built a combination groin-revetment, and one had property protected by an offshore structure (Z-wall), the effectiveness of each were 90 percent and 100 percent respectively. Replanting vegetation without further protection was found to be only 20 percent effective.

The mean cost of shoreline protective structure for all respondents to the questionnaire was $6,277, which translates into a front foot cost of $52 given the widths of the properties indicated by respondents. The distribution for the expenditure per front foot of a

shoreline protective structure as shown in Graph 9 demonstrates the reliance of most shoreline property owners on low cost protection.



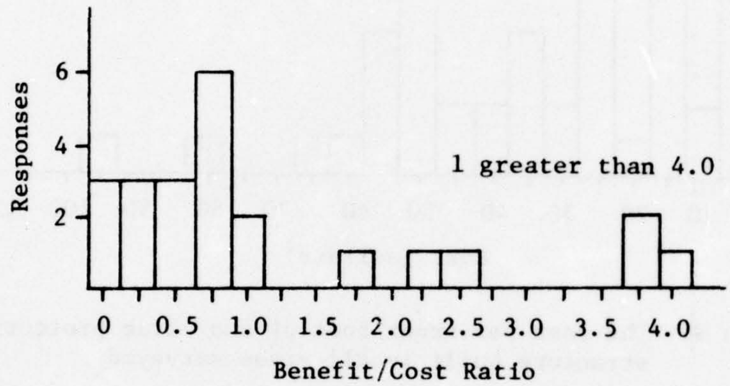

Graph 9. The cost per front foot of shoreline protective structure built in all areas surveyed.

To determine if a realtionship between the cost of a shoreline protective structure and its effectiveness existed, a correlation between these two variables was run. In the Grand Haven-West Olive area there was a correlation coefficient of -0.7056 which implies that as the cost of a protective structure declines, its effectiveness rises! In the Holland and Stevensville-New Buffalo areas there was no correlation, and in Benton Harbor-St. Joseph there was a weak positive correlation. It is thus important for a shoreline resident to be aware that the selection of a protective structure should not necessarily be based on cost alone. Figures 4 through 9 support this contention.

Shoreline property owners were asked what monetary difference the use of a protective structure had made on the value of their property. This information was utilized to quantify the magnitude of the benefit that the structure provided to the property owner. This benefit was then divided by the cost of the protective structure over the percentage effectiveness of the structure. This allows us to compute a benefit/cost ratio for a property owner according to his figures:

$$B/C = \frac{\text{Benefit}}{\text{Cost}/\%\ \text{Effectiveness}} = \frac{\text{Benefit} \times \%\ \text{Effectiveness}}{\text{Cost}}$$

The benefit will be reduced by the percentage effectiveness of the structure as the percentage declines. The mean value for those responding to this question (24) was 1.3 This implies that the benefits received from building a shoreline protective structure outweighed the costs. The benefit/cost ratio may actually be higher than this if the respondents accounted for the percentage effectiveness of the structure when indicating the increase in the value of their properties. The distribution of the values shown in Graph 10 indicate the majority had a benefit/cost ratio less than one, but that the very high values pulled the mean value above one.




Graph 10. Distribution of values for benefit/cost ratio of protective structures built in all areas.

Many shoreline property owners have taken no protective action for various reasons. Of those responding to the questionnaire, 62 took protective action and 62 did not. For those who said they did not take action, 12 indicated that the reason was little or no erosion, 20 because the action would not justify the cost, 16 because they could not make the expenditure, and 14 for various other reasons.

The questionnaire also asked the shoreline property owner how he would perceive the benefits and costs of building a hypothetical protective structure that would be 100 percent effective in stopping erosion. If they generally felt the benefits outweighed the costs, then the reasons for not building such a structure might be a lack of money. If this is true, then coastal management alternatives such as community projects financed by establishing an assessment district may be desirable.

The responses to this question did indicate in most cases that the benefit/cost ratio was greater than 1. In the Grand Haven-West Olive area the mean value was 1.035, and in Holland the mean value

increased to 1.605. In the Benton Harbor area the benefit/cost ratio was slightly greater than 1 (1.01), but in Stevensville-New Buffalo the mean value was only 0.4675.

## ALTERNATIVES TO SHORELINE PROTECTION STRUCTURES

### Beach Nourishment

Although shoreline protection structures are the most common method for controlling shoreline erosion, there are alternatives that may be more beneficial to the shoreline property owner. One method used frequently by the Army Corps of Engineers is beach nourishment. This involves extending the present beach to conform with its natural configuration by placing sand taken from inland or offshore sources. The sand is preferably of similar grain size to the natural beach. Its advantages are that the presence of a beach will not detract from recreational or aesthetic values and a beach is considered to be the best protection against bluff recession. The problems encountered with an artificial beach are: (1) that it will involve continuous replenishment during high water periods, and (2) may be expensive in those areas without a readily available source of sand. Even when inland sources are closely available, the mining of sand may involve environmental degradation and loss of flood protection in dune areas. A groin system used in conjunction with beach nourishment may resolve some of these problems.

Beach nourishment is seldom a means of protection used by private property owners in Michigan, so no cost or benefit figures were available. This alternative will be included in the next proposed phase of the benefit/cost study.

### Bluff Stabilization

The results from the questionnaire indicated that only two respondents attempted to stabilize their bluff by replanting lost vegetation, and that the effectiveness of such action was very low. If bluff stabilization techniques such as replanting vegetation are used in conjunction with an erosion control structure, the benefits may far outweigh the costs. Recall that 25 percent of the aesthetic value is lost when the vegetative cover of the bluff is lost. This 25 percent can only be recovered when the bluff has been restabilized. It will, of course, require generations before the large trees that were lost can regain their previous size, if ever. However, once the bluff has been attractively stabilized by vegetation, the lost aesthetic value will be regained.

This phase of the benefit/cost study did not attempt to measure the benefits and costs of effective bluff stabilization techniques because of a lack of data. During the next proposed phase, however, a study of techniques for vegetative stabilization of bluffs may be undertaken by Dr. Donald Gray, from which this study would draw.

## Home Moving Option

Another alternative which is becoming increasingly popular with shoreline property owners as they gain experience with the relative ineffectiveness of many shoreline protective structures is moving their home inland. This, of course, requires that the lot be deep enough to allow the home to be moved a distance great enough to justify the expenditure. When this option was available, the benefit/cost ratio was usually found to be greater than the alternative of building a shoreline protective structure. There are essentially two reasons for this. First, the costs of moving a home are competitive with a well-constructed shoreline protective structure. To move a cottage 30 feet by 50 feet with a basement, it will cost approximately \$5,000 to \$6,000, which is comparable to a protective structure costing \$50 per front foot. A house 54 feet by 60 feet recently cost the property owner about \$12,500 to move.

The second reason is that there will be no risk of erosion for many years, provided the home is moved back far enough. The new location will assure a prospective buyer that he will not be faced with large investments in shoreline protection.

There are also disadvantages that deter many shoreline property owners from taking such action. They may have paid a premium price for a lakeside lot that enables the owner to view the lake from the house. Moving the house will usually impair this view. It may also involve extensive cutting on a heavily wooded lot and require short-term relocation of the family while the house is being moved. Therefore, subjective values of shoreline property owners often override the economic advantages of moving a home.

To determine whether the home moving option is available, we assumed that there was a minimum existing depth of property that is required before a home can be moved. This distance included the set-back limitation established by the Michigan Department of Natural Resources for that location. If the long-term erosion rate is three feet per year, the set-back distance will be approximately 90 feet. The depth of the house, and 25 feet to allow for some distance between the house and the front edge of the lot are also included. A minimum number of feet between the house and the edge of the bluff is also required for safety of the home movers. This absolute minimum distance will be 20 feet. Therefore, to retain the home moving option, the depth of the lot must be greater than:

25' + Home Depth + Set-back + 20'

(Front of Lot) (Edge of Bluff)

If the set-back distance is 90 feet and the home depth 50 feet, the minimum required distance will be 185 feet. However, the house will be moved back only 110 feet from the edge of the bluff. If more room

is available, most property owners would probably move the home somewhat farther back.

The benefits to be gained from moving the home will be calculated in much the same manner as the benefits accruing to a shoreline protective structure. If the home has already lost some value before it is moved, this value will be regained because there is no longer any danger to the structure. Benefits will continue to be added as long as the home moving option is available. For example, the loss of structure value would continue until the edge of the bluff is 20 feet from the foundation of the home. This loss will be regained when the home is moved. This will frequently involve 70 percent of the value of the home. In most cases, the 75 percent of the aesthetic value and the simple land value will not have been lost because the lot is still deep enough to build on. The 25 percent of the aesthetic value that is lost when the vegetative cover of the bluff is eroded will not be regained by moving the house.

## LAKE LEVEL FLUCTUATION

The lake level study is an integral part of our model due to the ever present possibility that the lakes will substantially recede. One option of the homeowner is to "wait out" the high water period in hopes that significant damage will not be sustained. It would distort the true benefits, if this option was not recognized.

In order to include the effect of lake levels without being able to accurately predict them into the future, a statistical model has been developed (see Appendix G, "Shoreline Damage Survey: An Appraisal with Recommendations," for details). The model is designed to predict the probability that lake levels will exceed a critical level (described below) in a given year.

The concept of a "critical" lake level was first introduced by Maresca (1975).[1] The critical point defines the lake level at which the bluffline is in serious danger of erosion. The actual value of the critical level is site dependent, varying from one area to another. If the lake were to fall below this level, extensive bluff recession could occur only in the instance of a rare storm. Given that a critical level can be defined, we are concerned with the probability that this level will be equalled or exceeded by the mean lake level in a given year. As mentioned previously, the levels predicted by the model are probably not correct, due in part to the fact that no deterministic inputs were used. The variances on the predicted levels are large as would be expected. Table 1 displays the results of the autoregressive model for Lakes Michigan and Huron.

TABLE 1

LAKE LEVEL PREDICTIONS, 1975-1984

| Year | Predicted Level | Variance | Standard Deviation |
|---|---|---|---|
| 1975 | 580.01 | .288 | .536 |
| 1976 | 579.82 | .762 | .873 |
| 1977 | 579.66 | 1.068 | 1.033 |
| 1978 | 579.52 | 1.275 | 1.119 |
| 1979 | 579.40 | 1.359 | 1.166 |
| 1980 | 579.30 | 1.434 | 1.197 |
| 1982 | 579.15 | 1.530 | 1.237 |
| 1984 | 479.03 | 1.569 | 1.263 |

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[1] Joseph W. Maresca, Jr., "Bluffline Recession, Beach Change, and Nearshore Change Related to Storm Passages Along Southeastern Lake Michigan," Unpublished Ph.D. Thesis, University of Michigan (1975).

The following equations summarize the model: 1/

(1) $R_t = 1.2069 \times R_{t-1}(i) - 0.35264 \times R_{t-2}(i) + \varepsilon_t$

where: $R_t$ = residual in year 't' = $\hat{y}_t - \bar{y}$

$\hat{y}_t$ = predicted mean lake level in year 't'

$\bar{y}$ = 578.72 = mean lake level over the period of records--1860 to 1974

(2) $\hat{y}_t = \hat{R}_t + \bar{y}$

(3) $\hat{\varepsilon}_t = y_t - \hat{y}_t$

(4) $\hat{y}_t = \bar{y} + 1.2069 \times \hat{R}_{t-1}(i) - 0.35264 \times \hat{R}_{t-2}(i)$

Equation (4) allows the prediction of the lake levels shown above, by plugging in actual or computed residuals of the previous two years.

(i) = number of years previous to the year being predicted that actual residuals were used in the computation.

if (i) = 0, then $\hat{R}_{t-1}(0)$ = actual residual for 1974

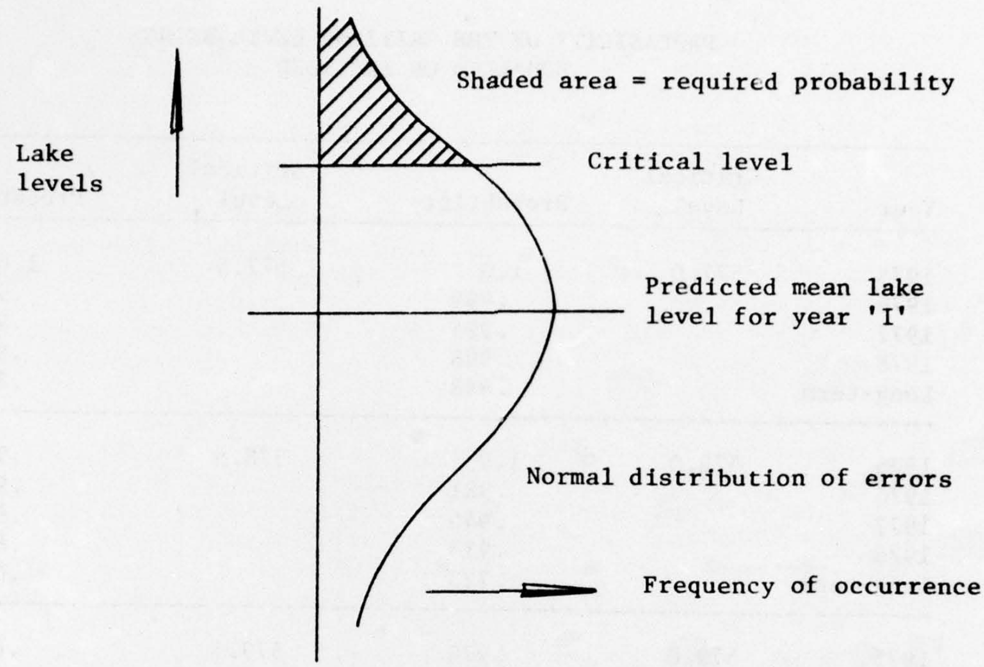
$\hat{R}_{t-2}(0)$ = actual residual for 1973

if (i) = 1, then $\hat{R}_{t-1}(1)$ = computed residual for 1975

$\hat{R}_{t-2}(2)$ = actual residual for 1974

Given any two intial residuals, the model (see Table 1) will have the lake tending toward the long-term mean (578.72). Though this is not the case in reality, we are concerned with the distribution of errors about the predicted mean, for this is the source of the "probabilities." If the errors are distributed normally, we can determine the probability that the critical level will be equalled or exceeded in the given year as is shown in the following diagram:

1/ The statistical model is not used by nor has it been indorsed by the U.S. Army Corps of Engineers. Review comments provided by representatives of the Corps of Engineers as well as the Univeristy of Michigan confirm the need to replace this statistical model in Phase II of this study effort.




A histogram of errors was constructed for each number of years into the future (1,2,3,. . .10) that predictions were made, by comparing the predicted levels to the records. After about four years into the future, the errors no longer distribute normally. 1/

In the benefit/cost model, the probability that the mean lake level will exceed the critical level in a given year is used to reduce the structure and home moving benefits. The initial four probability values from the statistical model are utilized (four years into the future), after which the "long-term" probability is inserted. The long-term probability is derived solely on the basis of the number of times the critical level has been exceeded in the past. The results are displayed in Table 2.

1/ This deficiency is one of the reasons for replacing the statistical model with a better model in Phase II of the study; see footnote 1, page 32.

TABLE 2

PROBABILITY OF THE CRITICAL LEVEL BEING EQUALLED OR EXCEEDED

| Year | Critical Level | Probability | Critical Level | Probability |
|---|---|---|---|---|
| 1975 | 577.0 | 1.0 | 577.5 | 1.0 |
| 1976 | | .999 | | .996 |
| 1977 | | .995 | | .982 |
| 1978 | | .988 | | .965 |
| Long-term | | .888 | | .804 |
| 1975 | 578.0 | 1.0 | 578.5 | .998 |
| 1976 | | .981 | | .934 |
| 1977 | | .946 | | .869 |
| 1978 | | .913 | | .819 |
| Long-term | | .723 | | .609 |
| 1975 | 579.0 | .970 | 579.5 | .823 |
| 1976 | | .826 | | .642 |
| 1977 | | .738 | | .561 |
| 1978 | | .679 | | .508 |
| Long-term | | .433 | | .280 |
| 1975 | 580.0 | .505 | | |
| 1976 | | .417 | | |
| 1977 | | .370 | | |
| 1978 | | .334 | | |
| Long-term | | .180 | | |

THE BENEFIT/COST MODEL

To assure that the benefit/cost model is fully understood, a decriptive presentation of the computer program will be provided. The flow diagram (Figure 10) can be used as a guide by the reader. An example using a shoreline property in West Olive will be discussed and contrasted with other examples so that the way in which real values of benefits and costs for a protective structure and home moving can be seen.

The current depth of this property from the edge of the bluff is 500 feet, and the house is 75 feet from the bluff. The high water recession rate is 13 feet per year, with a set-back distance of 90 feet. The total value of the lot and home is $60,000 with the home being valued at $30,000. The value of an inland lot is $5,000 (simple land value), which leaves $25,000 for the aesthetic value.

The program begins in year 0, which refers to the present. It first determines whether 25 percent of the aesthetic value has been lost, which occurs if there has been more than ten feet of bluff loss during the current high water period. If ten or more feet of bluff has been lost, we can be sure that most of the vegetative cover has been removed.

In this particular program, none of the lost values can be regained by moving the home or building a protective structure.* Only in the theoretical situation where a 100 percent effective structure was built which the market had complete confidence in could these values be regained during a high water period. It is very likely that the lost values would be regained if lake levels dropped significantly within the next ten years. However, the probabilities used in our model of lake level fluctuations indicate the greater likelihood of this remaining above average. The benefits accruing from a shoreline protective structure are thus derived from the protection of further value loss. Exceptions are noted below.

If the depth remaining is less than the distance over which simple land value is distributed (25 feet + home depth + set-back), and no house is present, the remaining 75 percent of the aesthetic value is lost. If a house is present, it is possible to sell the property at the premium price due to lakeside location, with the only loss in value being attributed to the structure itself. The rationale behind this stems from the fact that some lakeside lots were always smaller than the depth of simple land value, and yet they were sold with the aesthetic value intact.

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*This assumption in the model is probably not realistic and will be changed in future versions of the model.

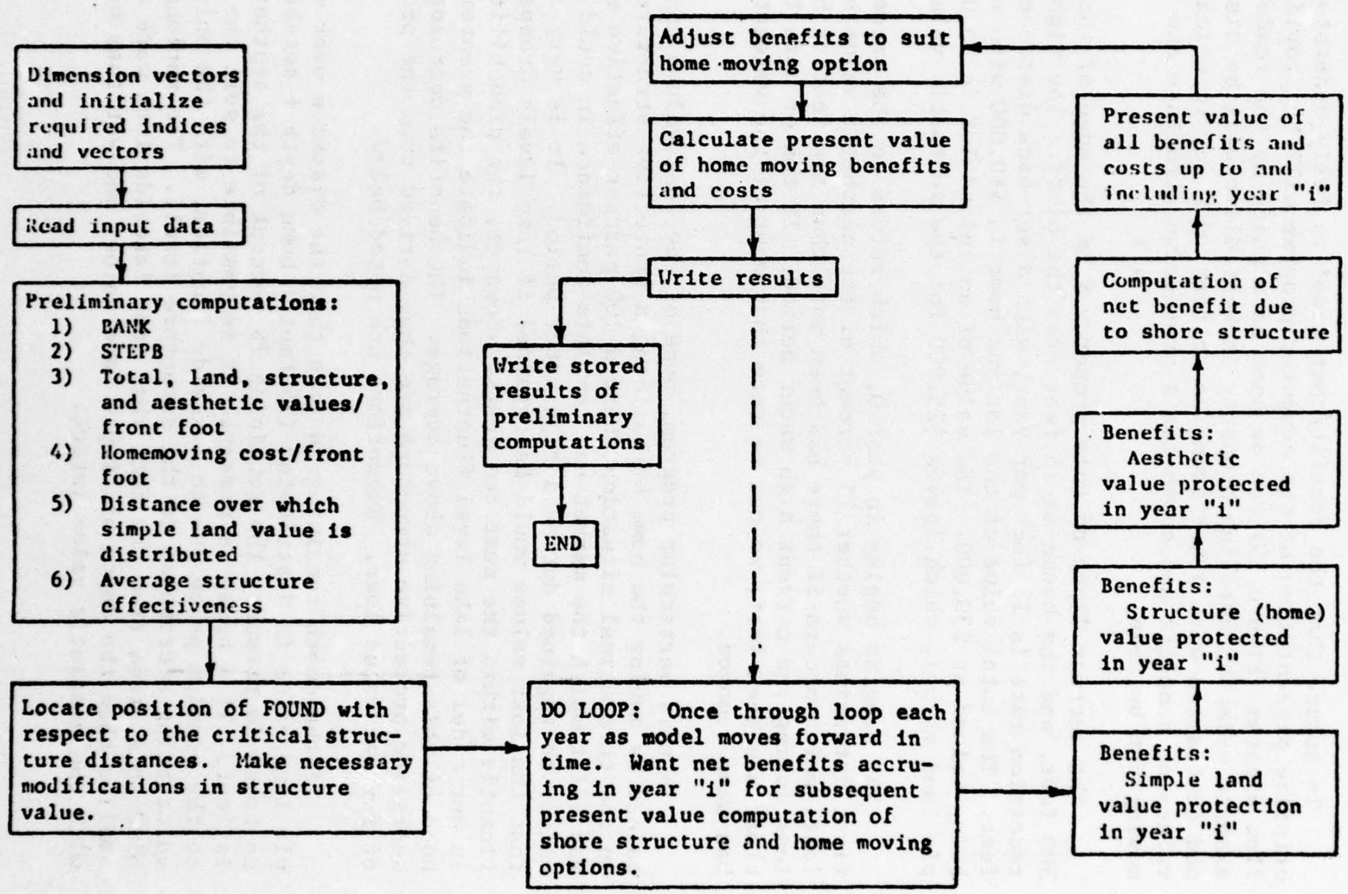

Figure 10. Flow Diagram of B/C Model

On a lot without a house that is smaller than the simple land value, the aesthetic value could be regained if an effective protective structure was built (arbitrarily set for this case at greater than 60 percent effectiveness over ten years). The DNR will allow a home to be constructed on property less deep than the distance over which simple land value is distributed if such a protective structure is built. Therefore, the "ability to build" is not lost. If lake levels were to remain at their present high, it is unlikely that the lot could be sold with the full 75 percent of its aesthetic value intact. However, the probability is that they will fall somewhat, in which case there is a possibility that a prospective buyer would then pay the premium price for the lot.

In year 0 the shoreline protective structure will be built, or the home will be moved, and these costs will be calculated in the present value formula. This formula is a means of determining the value of a protective structure with a stream of benefits over ten years to a shoreline property owner today. In terms of economics, there is a cost of waiting for these benefits, which is measured by the rate of interest. The present value formula is used in this model instead of a benefit/cost ratio; the formula being given as:

$$V = C_o + \frac{B_1 - C_1}{(1+i)} + \frac{B_2 - C_2}{(1+i)^2} + \frac{B_3 - C_3}{(1+i)^3} \; . \; . \; . \; \frac{B_n - C_n}{(1+i)^n}$$

Where: $V$ = present

$C_o$ = cost in year 0 (present)

$B_1$ = benefits in year 1

$C_1$ = cost in year 1

$i$ = rate of interest

$n$ = year n (variable)

The computer program also determines whether the home moving option is available in year 0, by calculating whether the present depth is greater than 25 feet + home depth + set-back + 20 feet. In the West Olive example this option is available (present depth = 500 feet).

The structure tested in this model is a wooden groin at a cost of \$60 per front foot. Therefore, the present value of this structure in year 0 equals -\$60 per front foot because there are no benefits accruing at the present time. The home moving cost is calculated at 20 percent of the value of the home, so that the present value of the moving option is -\$60 per front foot.

In years 1 through 10 the benefits are calculated from the same procedure in which they were explained throughout this report. The depth of the property is decreased each year by the recession rate,

and any values that are lost by this decrease in depth are added to the benefits per front foot. For example, the program first checks to see whether any simple land value has been lost by computing the area of the trapezoid that is no longer present. The same is true for any structure value lost. The only deviation from this is for the home moving option, where the recession rate is reduced by the probability of the critical lake level being equalled or exceeded.

In year 1, as benefits are added, the present value of the structure increases to -$32.98 per front foot, and the home moving option to $14.38 per front foot. In year 2 when the edge of the bluff is 49 feet from the house, which is no longer salable, the present value of the protective structure is $22.75 per front foot, and the home moving option $104.54 per front foot. In year 5 the home moving option is no longer feasible because the bluff is less than 20 feet from the foundation of the house. Therefore, we compare the present value of the home moving option ($104.54) to the present value of the protective structure ($15.47). Subjective value considerations aside, this study would recommend that the property owner move his house back. If the present value formula is carried through to year 10, the protective structure eventually would have a present value of $29.78 per front foot.

An example from the Benton Harbor area illustrates a situation where no shoreline protective structure would be recommended. The depth of the property is 600 feet, and the total value of the house and lot is $55,000. However, the house is presently 140 feet from the edge of the bluff and the high water recession rate is only 1.7 feet per year. Therefore, after ten years the bluff would have only receded 17 feet if the lake level had remained at its present high. However, since this property had experienced very little erosion to date, the critical level here must be very high. In other words, the lake level at which the bluff would begin to erode is much higher than for a property that had experienced extensive erosion throughout the high water period. Therefore, the probability that this critical level will be equalled or exceeded within the next ten years is very small. The amount of bluff recession that this property owner could expect during the next ten years is thus much less than 17 feet. As the computer output indicates (see Appendix 2), there has been no decline in property values for this property. The present values for the various structures are -$70.07 for a wooden groin, -$85.00 for a steel seawall, -$29.77 for a wooden seawall, -$83.55 for a sandbag seawall, -$83.55 for a sandbag groin, and -$200.00 for a stone revetment. These present values are all given on a front foot basis.

Another example is from a property in West Olive where the house is presently only four feet from the edge of the bluff. The present value of this house is only $5,000, but the lot, because of its size (1000' x 200') is valued at $60,000. The high water recession rate

is 6.7 feet per year, which means the house will have fallen over the bluff in one year.

The original value of the house was in excess of $16,000, but 70 percent of that value has already been lost. Consequently, there will be only minor benefits derived from protecting that property. In fact, the benefits in year 1 will be only $25.00 per front foot. We are assuming that if a structure is built, it will extend along the entire reach of the property. The net benefits for any of the shoreline structures were, of course, negative as no structure tested cost less than $25.00 per front foot.

There are some differences between structures due to their initial effectiveness. For example, a wooden groin has an effectiveness in year 1 of only 43 percent. Therefore, the net benefit for this structure in year 1 is only $4.61. For the stone revetment, that is 100 percent effective in year 1, the net benefit is $24.25. These differences in net benefits for one year will not be important in most cases, because the house is usually far enough back from the edge of the bluff so that the concern will be with net benefits over a ten-year period.

The home moving option was not available for this house because it was too close to the edge of the bluff. If the property owner had taken action sooner, the home moving option would have proved to be economical.

The lot has lost no value except for 25 percent of the aesthetic value because it is still deep enough to build on. Even when the house falls in, the property value will be $60,000.

In another of the examples tested, we found a positive present value for each of the six structures listed. This property is located in New Buffalo, Michigan, and the information we received indicated a high water recession rate of 20 feet per year. The depth of the property is only 160 feet, so the home moving option is not feasible. The house, which is currently valued at $55,000, is 30 feet from the edge of the bluff. The lot is only 80 feet wide, so there is a high total value per front foot of $937.50.

A great deal of this value is lost in year 2, when the house would have fallen in if no protective action was taken. The lot is no longer deep enough to build on at this time, so the aesthetic value and part of the simple land value is also lost. The benefit in year 2 thus equalled $876.09 per front foot for a wooden groin. The net benefit in that year was reduced however, by the effectiveness of the structure and the probability that lake level will decline, to $487.12 per front foot. Because of the high value of the property that a structure would protect, the close proximity of the house to the bluff, and the high rate of recession, the greatest benefits were found to accrue from the stone revetment ($371.16 per

front foot). The wooden groin would have been the next best alternative, yielding $306.83 per front foot. For this example, all of the structures were justified.

## MODEL PROGRAM

The program is writen in the Fortran-IV computing language, and can be run using the Fortran-G or Watfiv compilers on the Michigan Terminal System. For simplicity, non-formatted input is used. If a multitude of trial runs are to be made, an object code file should be created. This saves compilation time which is five times greater than the execution time of the program.

### Key Variables

Multi 1, multi 2 = multipliers

A = weighting factor

T = time of study (years)

CO = structure cost ($/front foot of protection)

C(I) = maintenance cost in year 'I' ($/front foot)

RI = interest rate

B(I) = total benefit in year 'I' ($/front foot)

S(I) = net benefit in year 'I' ($/front foot)

TV = total value of the lot ($)

LV = inland land value = simple land value ($)

SET = set-back distance by DNR (ft)

RSET = recommended set-back by DNR (ft)

TH = natural angle of bluff material (Radians)

H = height of bluff (ft)

SV = structure value - home and other buildings ($)

RESR = average high water recession rate (ft/yr)

RESRL = long-term RESR (ft/yr)

L = length of lot - frontage (ft)

HOMED = home depth (ft)

REST = realtor estimate of BANK (ft)

BANK = distance from house to bluff at which bank will not mortgage the property

STEPL = distance from house to bluff at which an initial sharp decline in value occurs (ft)

FOUND = distance from home to bluff edge when study is being made (ft)

REC = recession of bluff during recent high water period (ft)

## How to Input Program

Two namelist groups, DIN (data in) and DIN2 composed of five data cards, are required for each run of the program. Each variable in the namelist is separated from the next by a comma, and the first space of each card is skipped.

First Card:

_&DIN_DEPTH=__.,SET=__.,FOUND=__.,TH=.__,TV=__.,SV=__.,LV=__.,

Second Card:

_RESR=__.,RESRL=__.,HOMED=__.,T=__.,L=__.,RSET=__.,REC=__.,STEPL=__.,

Third Card:

__CO=__.,RI=.__,REST=__.,A=.__,MULT1+__.,MULT2=.__,_&END

Fourth Card:

_&DIN2_EFF(1)=__,__,__,__,__,__,__,__,__,__,C(1)=__,__,__,__,__,__,__,
__,__,__,

Fifth Card:

_PROB(1)=__,__,__,__,__,__,__,__,__,__,II=__,_&END

The blanks on the fourth and fifth cards are shown as if the study were to extend ten years into the future. II tells the program which structure type is being studied; the corresponding CO,C(I), and EFF(I) having been inputted.

II = 1 implies steel seawall
2 " wooden seawall
3 " wooden groin
4 " sandbag seawall
5 " sandbag groin
6 " rock revetment

These six structure types were selected because of their frequent occurrence in our study area. Assuming the program is already compiled in the file CBØB (cost/benefit object program), it could be run for three different examples on MTS as follows:

```
$SIGNON  CCID  T = 2

PASSWD

$RUN CBOB

     Date Cards

$ENDFILE

$RUN CBOB

     Data Cards

$ENDFILE

$RUN CBOB

     Data Cards

$ENDFILE

$SIGNOFF
```

## CONCLUSION

As indicated earlier, the benefit/cost model is an ongoing study. Therefore, any conclusions reached are purely tentative. The manner in which shoreline property values decline as the bluff recedes will be verified or altered by further realtor consultation. The structure effectiveness curves will undergo extensive revamping as more precise data is obtained.

Notwithstanding, this study in its present form can be a valuable decision making tool for selecting shoreline protective structures. The selection of these structures can now be based on sound economic and engineering principles which provide shoreline property owners with a rational basis for alternative action.

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Benefit/Cost Questionnaire

NAME ______________________________

ADDRESS ______________________________

CITY ______________ TOWNSHIP ______________

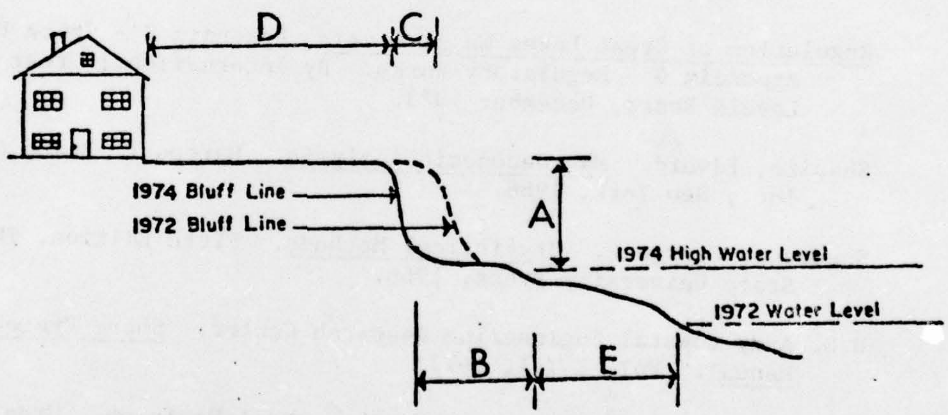
STATE ______________ ZIP ______________

1. Do you own this property?
   Yes___ No___

2. How many months each year do you reside at this address?
   ________months

3. What is the length of your shoreline frontage?
   ________feet

4. How many feet back from the present shoreline does your property extend? ( Approximate "depth" )
   ________feet




Referring to the diagram given above, please answer the following questions.

5. What is the approximate height of the bluff or embankment above the existing water level?
   ________feet
   distance "A" above

6. How deep is your present beach?
   ________feet
   distance "B" above

7. Estimate the month and year that your property began to experience bluff loss due to erosion. (We are only concerned with the recent high water period beginning in 1969.)

_______________

8. If you bought this property after bluff loss had already begun, please indicate the date of purchase.

_______________

9. What is the depth of bluff loss due to erosion since the date given in question 5 or 6?

_______________ feet
distance "C" above

10. Estimate the present distance between the edge of the bluff to the foundations of your house.

_______________ feet
distance "D" above

11. How many feet of beach have you lost since the date given in question 5 or 6?

_______________ feet
distance "E" above

12. What was the value of your property just prior to the date given in question 5?

$_______________

13. If you answered question 6, please indicate what you paid for the property on that date.

$_______________

14. Estimate the value of your lot on the date given in question 5 or 6?

$_______________

15. Estimate the value of the same size lot in your area, not on the lake?

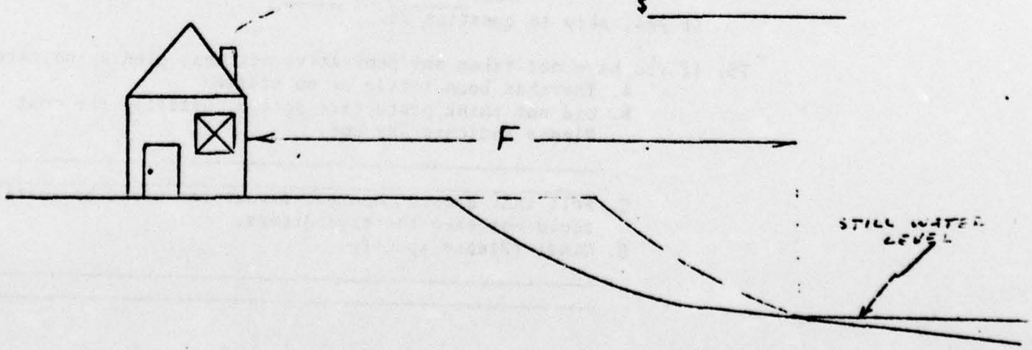
$_______________

16. What is the present value of your property?

$_______________

17. If the lake levels were now to recede such that you were no longer in danger of erosion, how much do you think your property would be worth?

$_______________



18. Estimate the distance from the bluff to your house at which your property began to decline in value. (i.e. that distance where you could no longer sell your property at its full value)

_____________feet

distance "F" above

As you know, porperty along the shoreline is much more expensive than land that does not border the shore. The following questions are designed to find out what it is about living on the lake that people value, and how erosion affects these values.

19. On a percentage scale, indicate the particular values that living on the lake hold for you. (Your total should add up to 100%. For example, aesthetic beauty 80%, recreation 20%.)

Aesthetic beauty _______________%
Recreational value _______________%
Other _______________%
(Please specify)_______________

_______________

20. Estimate how these values have declined as a result of shoreline erosion. (For example, the recreational value of my property has declined 50%.)

Aesthetic beauty _______________%
Recreational value _______________%
Other _______________%

21. Do you think that the market value of your property has declined because these aesthetic and recreational values have declined?

Yes _____ No _____

22. How much has the decline in these values contributed to the total loss in the market value of your property?

Recreational value $_______________
Aesthetic value $_______________
Other $_______________

23. Is your neighborhood zoned residential?

Yes _____ No _____

24. Have you built any protective structure or taken any protective action since 1969?

Yes _____ No _____

If yes, skip to question 26.

25. If you have not taken any protective actions, please indicate why not.

A. Therehas beon little or no erosion
B. Did not think protective action justified the cost
Please indicate why not.

_______________

_______________

C. Felt that erosion control structures might be justified, but could not make the expenditure.
D. Other (Please specify).

_______________

_______________

26. What protective action have you taken?
______________________________________________
______________________________________________

27. On a percentage basis, estimate howw effective your protective action has been in stopping erosion.(i.e. 50% effective in stopping erosion)
______________%

28. How much did this action cost?
$______________

29. Would you expect a higher sale price for your property because you have a protective structure, than if one was not present? If so, how much?
No ______ Yes _____ / $______________

30. How much do you think it would cost to build a protective structure for stopping erosion of your property?
$______________

31. If such a structure were built, how much would the value of your property increase?
$______________

COMMENTS: